

Stabilization of the Elementary Particle by Self-Gravitational
Forces

By

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SUMMARY

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A classical spherical model of the elementary particle is always used to prove that self-gravitational effects in the elementary particle, such as the electron, are insignificant compared with electric effects and are, therefore, of no consequence. Considerations of cosmical, force-free configurations and force-free configurations recently produced in the laboratory suggest a force-free torus model for the elementary particle. With a torus model, it can be shown that self-gravitational effects can be comparable to electromagnetic effects in the elementary particle and that the electron and proton can, therefore, be stabilized by self-gravitational forces.

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This essay will attempt to demonstrate that with appropriate torus models of the elementary particles, it is possible to stabilize the electromagnetic field of *such* particles by means of the self-gravitational forces associated with that electromagnetic field.

Recent theoretical work in astrophysical hydromagnetics by Schlüter and Chandrasekhar has shown that there may exist in the cosmos, force-free configurations consisting of electrically-conducting hydrogen plasma (protons and electrons in equal numbers) and magnetic fields where the electric current, magnetic field, and mass motions are all parallel.

For any practical force-free configuration involving plasma and magnetic field, such as a torus of plasma with magnetic field lines which thread it helically with pitch angles varying from 90° at the annular axis to approximately zero at the periphery, true equilibrium is possible only if there is some cohesive force like gravitational forces to counteract the general expanding effects produced by the magnetic fields and the thermal energy of the plasma. On a cosmic scale, the masses can be large enough for gravitational forces to supply this necessary stabilizing influence. A force-free cosmical configuration can be expected to have no distorting forces to change the configuration. One can imagine that nature is actually aware of the possibility of such a configuration, that

she covets this equilibrium condition, and that any non-equilibrium configuration of plasma, electric currents, and magnetic fields, in which there are unbalanced forces, will be pushed by these forces instinctively into the shape of the force-free configuration.

The importance of such force-free configurations to the organization of the cosmos is underscored by a realization that about 99% of the mass of the Universe is in the form of interstellar hydrogen, a large fraction of which may exist in the ionized state, and that nature seems to be able to produce magnetic fields at will in fluid conducting bodies where the magnetic Reynolds numbers are high (viz. the sun, the star, the galaxies).

In 1955 the importance of developing force-free coils for the production of high magnetic fields in the laboratory ~~was~~ been pointed out by Levine, Furth, and Wanniek. Within the last few months, Levine and Koncius have demonstrated that a magnetic field of 120,000 gauss can be produced by a force-free laboratory coil made of a thin shell of copper which would otherwise be crushed by such a high magnetic field pressure. Their force-free coil is, of course, only an approximation to a true force-free configuration. In place of self-gravitational forces of the coil (which on the laboratory scale are too small to be of any consequence), Levine and Koncius supply a rigid surrounding yoke which counteracts the general tendency to expand. The coil then retains its shape at these high fields. Thus man has been able to construct with copper in the laboratory an approximation to the force-free principle which he believes may be operative on a cosmical scale, at least 10^{22} larger than his laboratory coil.

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In late 1955 and early 1956, Bostick and Twite were able to produce and photograph luminous plasma jets which, when fired across a magnetic field in the presence of a conducting medium, exhibit the instinct and ability to organize themselves into helixes, barred spirals, many-armed spirals, or ring spirals. Theoretical scaling arguments together with the fidelity with which such galactic configurations can be reproduced in the laboratory give us a good hydromagnetic hypothesis for the explanation of the galactic arms and the description of the galactic magnetic field. Indeed, this new understanding can lead us to formulate an electric current pattern which shows how the galaxy can be a regenerative self-excited dynamo which continuously transforms gravitational energy into galactic magnetic-field energy. Experimental evidence suggests that some of these laboratory configurations may be force-free toruses. The toruses in this case are immersed in an externally excited magnetic field, the coils of which bear the forces which would otherwise expand the toruses.

In passing from the cosmical force-free configurations to the laboratory force-free dimensions of about 10 cm, we have engaged in a dimension reduction by a factor of at least 10^{22} , without "shaking" the force-free principle. We now invite the reader to let his imagination engage in a further reduction by a factor of 10^{14} to the scale of the elementary particle. We propose a hydromagnetic torus model of the elementary particle, and in this proposal, we have an advantage over the classical models of Lorentz

and Kelvin because we now have knowledge of the subject of hydromagnetics which is only about 12 years old.

The renormalization program of the new quantum electrodynamics has been successful in camouflaging the difficulties involved with the infinite self-energy of a point-charge elementary particle. But the present quantum electrodynamics is powerless to answer the question of how the electric and magnetic fields associated with the elementary particle can exist in a stable configuration. With the hydromagnetic-torus model we attempt to answer such a question. In the ^psimplest hydromagnetic model we assume that the charge e of the elementary particle is uniformly distributed over the shell of a torus of large radius R and small radius r_0 . If this charge is in circulation with a velocity c , there is equilibrium of the electric field E and magnetic field H about the small radius r_0 ; and the angular momentum carried by the poynting vector will prevent the ^ssavage and kink type of instability, to which the ordinary pinch effect is subject. However, there will be a general expanding tendency to increase the large radius R . Such a particle would thus be unstable, like a π or μ meson.

Its rest massenergy $m_0 c^2$ should be equated to its electromagnetic-field energy, $E_f = \int_{\text{all space}} (\frac{1}{8} \pi) (E^2 + H^2) dV = \frac{e^2}{R} \left(1 + \frac{1}{\pi} \ln R/r_0 \right)$.

The radius R for torus models can be determined from the measured magnetic moments to be $R = \frac{\hbar}{m_e c}$ for the electron, and

$R = \frac{2.8\hbar}{m_p c}$ for the proton. The determination of R for the mesons is more difficult because of our lack of knowledge of their magnetic moments. For example, if, for the μ meson, we should use a value of R equal to that for the proton, the relationship $E_f = m_0 c^2$ gives a value of $\ln R/r_0 \approx 137$. Indeed, with $\ln R/r_0 \approx 137$ the angular momentum carried by the poynting vector, calculated on a classical basis for this model to be $|S| = (2e^2/\pi c) \ln R/r_0 \text{ erg sec.}$, gives a value of spin equal approximately to $\frac{1}{2}$.

To produce a torus model of a stable particle, like the electron or proton, it will be necessary to invoke a cohesive force such as a self-gravitational force, just as a truly stabilized force-free cosmoical configuration must have self-gravitational forces. For the last half century, physicists have been glibly showing by a simple Newtonian calculation that the self-gravitational potential energy of the electron, $-\frac{G m_e^2}{2 r_e}$, is so much smaller than the electrical energy, and that hence the self-gravitational forces cannot be of any consequence in the construction of the elementary particle (r_e is the classical radius of the electron, and G is the gravitational constant, $6.67 \cdot 10^{-8}$ cgs). These calculations use a spherical model. If, however, we now use a torus model it is easy to show that the self-gravitational potential energy E_g associated with the mass density distribution, $(E^2 + H^2)/8\pi c^2$, can be made comparable in magnitude with the electromagnetic field energy E_f . Thus we can think in terms of a torus model stabilized by self-gravitational forces. This stability,

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a simple Newtonian calculation, involves very small values of r_0 . Indeed, for the electron $\ln R/m_0 = 1.5 \times 10^{24}$, but still there are no self-energy infinities to cope with as there are in a point distribution of charge. We are not dismayed by the hard-headed, long-haired interpretations of the uncertainty principle which would classify small dimensions such as r_0 as unobservable and therefore non-existent. Although we will never be able to see beyond the radius of the observable universe, our imagination can transport us into the region beyond to assure us that in that region there certainly do exist galaxies and stars. In like manner our imagination has the privilege of transporting us beyond the limits of the uncertainty principle to inquire into the reasons for the existence and stability of elementary particles.

We can now understand in a new light Einstein's first cosmological solution in which he calculated that the electromagnetic field was condensed into elementary particles by an average cohesive pressure $p = -\frac{\rho}{2}$ where ρ is the average mass density of the Universe and the radius a of the Universe is given in terms of the mass M of the Universe by $a = 2 GM/\pi c^2$. He had both the expansion of the Universe and continuous creation in his hand with this solution if he had only known at the time that a should increase with time. The Einstein cohesive pressure $p = -\frac{\rho}{2}$ we now identify per particle (electron and proton) with our self-gravitational potential energy E_g in the torus model, and since $E_f + E_g$ must equal $m_0 c^2$, $E_f = \frac{3}{2} m_0 c^2$, and $E_g = -\frac{1}{2} m_0 c^2$. The Einstein density ρ is identified per particle with $m_0 c^2 (= E_f + E_g)$. The density ρ' of electro-

magnetic field energy alone (without the correction due to E_g) is that given by Hoyle, $\rho' = \frac{3c^2}{8\pi G a^2}$, for continuous creation. Furthermore, according to the solution by Einstein, the rest mass ^{energy} of a particle, $m_0 c^2$, is approximately equal to gravitational potential energy of a particle of mass m_0 in the Universe of mass M since $m_0 c^2 \approx G M m_0 / a$. Thus it is quite likely that the entire energy of the Universe is and always has been zero. Continuous creation can be understood in a simple Newtonian sense as a transaction in which no net energy is created: when positive energy, $m_0 c^2$ comes into being the Universe takes an equal negative step in its gravitational potential energy.

To prevent a collapse of the model into a negative gravitational infinity, it is necessary to have the charge distributed throughout the volume of the torus and to have the magnetic field lines thread the torus helically in force-free fashion. The angular momentum of the poynting vector can thus prevent the collapse of the torus about \hbar_0 . These helical magnetic field lines can be expected to twist the elementary particle into a helix which will then exhibit a wave length which can be identified with the de Broglie waves. Indeed, we can bring forth descriptions which will make it plausible that such a particle can pass through two slits at once and produce appropriate diffraction effects.

Thus the hydromagnetic torus model promises a rich insight into questions such as the origin, stability, and behavior of matter in the Universe.